Investigation of Tropospheric Transport from Backward Trajectory Modeling of Volcanic SO2

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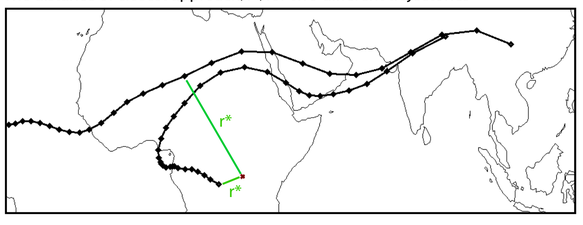
Abstract

Volcanoes represent point sources of atmospheric tracers that are often injected into the mid/upper troposphere and as such offer a unique opportunity to study atmospheric transport and mixing. Here we explore trajectory modeling of degassed volcanic SO2 as a possible means to evaluate the quality of analysis winds since the location of the source is known, however there are several challenges using this approach. The work presented here is a Lagrangian study of several volcanic events for which both OMI column integrated SO2 and CALIPSO aerosol attenuated backscatter measurements are available, thus the altitude of the SO2 is known. Backward trajectories from measurements far from the volcano using different winds (NCEP Reanalysis, NASA/GMAO/GEOS-5,GEOS-4) are compared. The study raises some interesting questions about what can reasonably be expected when attempting to validate winds by tracking measurements backward in time.

Methods

Parcels are initialized at the locations of high OMI column SO2 measurements at vertical locations that are known from collocated Calipso AOD measurements. Isentropic back trajectories are run using the Goddard Trajectory Model at several theta levels from 330K to 380K, including those near the altitude of the Calipso measurement. NCEP Reanalysis (2.5x2.5) degree and NASA/Goddard GEOS4 (1.25x1) degree and GEOS5 (2/3x1/2) degree winds are used in this study.

The distance of closest approach, r*, for two different trajectories



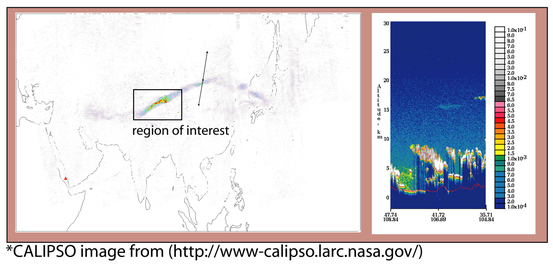
For each parcel, we compute r*=distance of closest approach of the parcel to the volcano and t*, the time of closest approach.

The Transport Test: Do parcels track back to the volcano at the correct (as observed by Calipso) altitude? Is the PDF of arrival time t* consistent with the known emission time? Does the PDF of r* peak at relatively small values for parcels traveling at altitudes of observed high attenuated backscatter?

Volcanic Eruption Case Studies

Jebel - al -Tair, Yemen

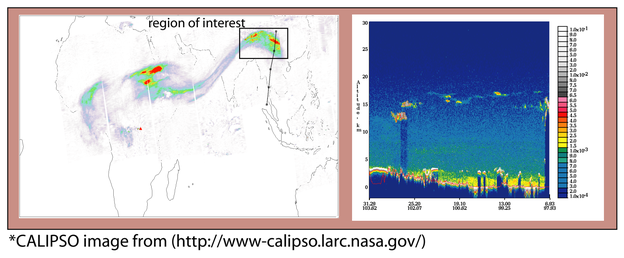
10 / 05 / 2007



*CALIPSO image from (http://www-calipso.larc.nasa.gov/)

Nyamurangia, DR Congo

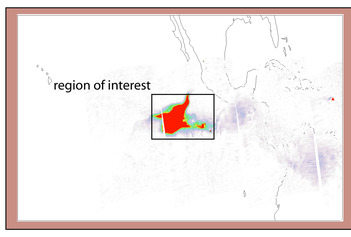
12 / 05 / 2006



*CALIPSO image from (http://www-calipso.larc.nasa.gov/)

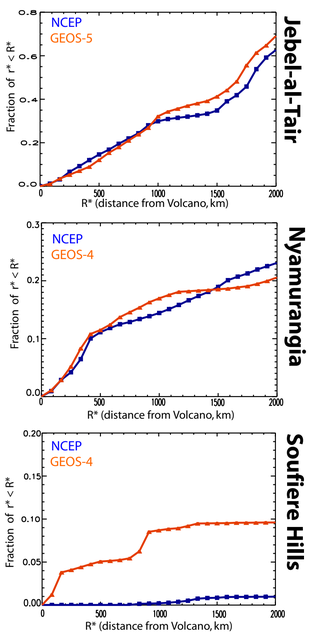
Soufiere Hills

05 / 25 / 2006



CALIPSO data not available, but published papers have confirmed the height of this SO2 cloud to be ~ 20 km

How many parcels arrive at the volcano within a given distance (R*) at any altitude? Similar CDFs here indicate similar transport but a possible shift in the vertical location of the subtropical jet.



CDF's (Cumulative Distribution Functions) of r* for each eruption

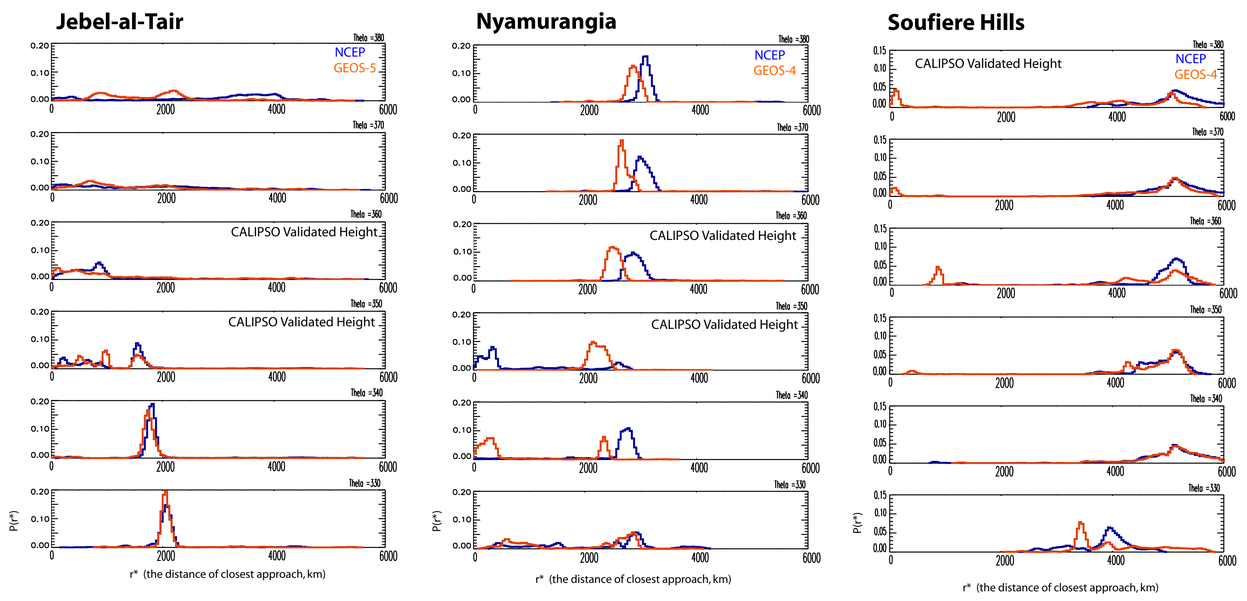
Look at regions that a relatively close to the volcano (R* < 2000)

Jebel-al-Tair and Nyamurangia Eruptions:
no strong difference in the CDF of r*.

Soufiere Hills eruption:
a strong disagreement between the NCEP and the GEOS-4 CDF.

Which theta levels track back to the volcano?

PDF's of r* for individual theta-levels (for each eruption)



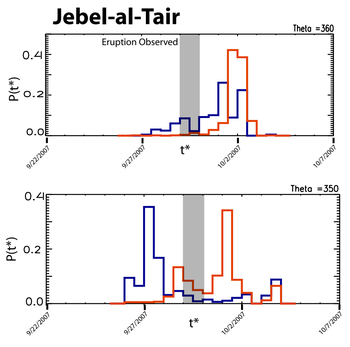
Both wind analyses suggest that parcels initialized at the CALIPSO verified height track back closest to the volcano.

NCEP tracks parcels back to the volcano on a vertical level verified by CALIPSO, GOES-4 does not track parcels back close to the volcano at this level.

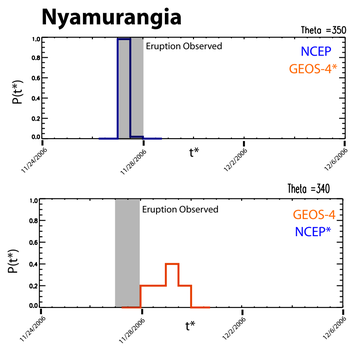
NCEP does not track any parcels back to a close proximity of the volcano, GOES-4 tracks parcels back to the volcano at the levels suggested by CALIPSO

What time do parcels arrive at the volcano?

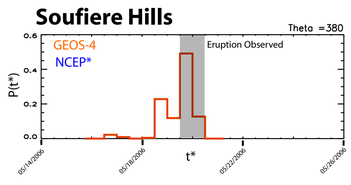
We look only at parcels where r* < 1500 km on the theta levels that were suggested from the r* PDF's



Neither NCEP nor GEOS-5 arrive at the volcano at the observed eruption time, on either the 350K or the 360K levels.



NCEP parcels arrive at the volcano at the observed injection time, while GOES-4 parcels arrive at the volcano too early.



GEOS-4 parcels arrive at the volcano at the observed eruption time.

* not enought parcels for GEOS-4 at this theta level

* not enought parcels for NCEP at this theta level

Results

NCEP:
- For the Jebel-al-Tair and Nyamurangia eruptions, NCEP tracks parcels back close to volcano on theta levels consistent with CALIPSO measurements.
- Suggests the correct eruption time for Nyamurangia but not for the Jebel-al-Tair.

GEOS-4:
- Tracks parcels back to the volcano on the correct theta level and time for the Soufriere Hills eruption, but not Nyamurangia

GEOS-5:
- Tracks parcels back to the volcano on the correct theta level, but not at the correct time (Jebel-al-Tair eruption)

Conclusions

The transport conditions and altitudes of the Jebel-al-Tair and Nyamurangia eruptions were very similar. In both cases, the so2 moved northward and became entrained in the subtropical jet. The NCEP reanalysis winds are consistent with the observed so2 transport in this region. However, NCEP transport doesn't agree with the observed motion of the so2 for the Soufiere Hills eruption which launched so2 into the equatorial lower stratosphere.

The GEOS-5 transport agrees the observed so2 motion in the region of the Jebelal-Tair and Nyamurangia eruption: GEOS-4 gives poorer results in this region.

The GEOS-4 winds tracked so2 in lower stratosphere near the Soufiere eruption better than the upper tropospheric so2 near the Nyamurangia eruption.

A statistical study that includes many volcanic eruptions, for which the altitude and emission time are known, is necessary for a robust assessment of the quality of analysis winds in the upper troposphere and lower stratosphere. The results presented here indicated that this method may be a promising tool in this investigation.